A FARMERS GUIDE TO EVALUATE SOIL HEALTH USING PHYSICAL, CHEMICAL, AND BIOLOGICAL INDICATORS ON AN AGRICULTURAL FIELD IN ALASKA

By

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Abstract

Farmers across Alaska face many challenges. These challenges include climate extremes, wind and water erosion, weed pressure, crop pests, and nutrient-poor soils. Cover crops, crop rotation, crop residue, and tillage management are common conservation practices used to address soil related resource concerns. Research in the continental United States has shown that these soil conservation practices improve soil health. Resource managers are trying to determine the usefulness of soil health indicators to assess conservation practices in Alaska. The objective of this project was to provide Alaskan farmers, conservation planners, and land managers with a background on soil health, soil health indicators, soil health assessments, and the use of conservation practices to improve soil health. Establishing linkages between soil conservation practices and soil health indicators will allow individuals to focus conservation efforts on improving soil conditions, evaluate soil management practices and techniques over time to determine trends, make qualitative comparisons of soil health among management systems, and provide tested measures of soil health (indicators) that will allow farmers and land managers to make more informed resource decisions. Numerous studies were conducted across Alaska to gauge the success of cover cropping, crop rotation, and reduced tillage (no-till). Improvements in physical, chemical, and biological indicators were documented. After one year of study, most cover crops resulted in lower bulk density at the soil surface compared to conventional tillage. Among the cover crop treatments, the perennial forage grass Timothy (*Phleum pratense var.* Engmo) ranked highest in soil organic matter, soil water content, and improvement to the soil structure. Preliminary data from this project has been gathered to develop an Alaska specific Soil Health Assessment Card and supplementary User Guide.

Acknowledgements

I would like to thank Casey Dinkel and the staff at the Alaska Plant Materials Center for their assistance with trial design, collection of samples, and operation of equipment. I also appreciate and thank staff members of the Homer, Kodiak, Kenai, Palmer, and Fairbanks Soil and Water Conservation Districts for their many hours of field work and contributions to the development of the Alaska Soil Health Card. I want to recognize the work of Casey Matney of the University of Alaska Cooperative Extension Service Kenai Peninsula District Office for his assistance to multiple Conservation Districts with trial design and data analysis. I'd like to acknowledge Craig Smith, Agronomist with the Alaska Natural Resources Conservation Service, for his contributions to define species composition of cover crop mixes and multiple trial designs. A special thanks to committee chair Mingchu Zhang, committee members Meriam Karlsson and Casey Matney for the support throughout the course of the project.

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CHAPTER 1: BACKGROUND IN SOIL HEALTH

Defining Soil Health

The idea of '*soil health*' or '*soil quality*' has been heavily discussed since the early 1980's and has recently resurfaced within the Natural Resources Conservation Service (NRCS), as evidenced by the formation of the Soil Health Division. Much debate has been had over using the words *soil health* or *soil quality*. Interestingly, many consider a benefit to using the terms interchangeably. The focus on quantitative and analytical soil properties and how these properties link among soil system functions is reason for scientists to favor the term *soil quality* (Romig et al., 1995). In contrast, farmers prefer *soil health* as it is a more descriptive term, i.e. a healthy farm versus an unhealthy farm (Romig et al, 1995). The term *soil quality* may better apply to a soil as a component of a larger ecosystem that supports plant growth, regulates water, cycle's nutrients and so on. Both terms are currently used in scientific literature, however *soil quality* is more common and may have preceded the concept of *soil health* (Weil and Brady, 2016). For purpose of this manuscript, we will center our focus on and use the term *soil health*.

A widely accepted definition of soil health is merely *the capacity of a soil to function.* (Karlen et al., 1997). Karlen et al. (1997) offer an expanded definition as "the ability of a soil type to function within natural or managed ecosystems boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation." Doran and Parkin (1994) propose a similar definition. Soil health functions like a three legged stool, the three components being sustained plant and animal health, biological productivity, and environmental quality (Karlen et al., 1997). Others define soil health as the soils *fitness* to support crop growth without becoming degraded or otherwise harming the environment (Acton and Gregorich, 1995). Though definitions may vary, most would agree that healthy soils demonstrate the capacity to function as a vital, living ecosystem that sustain plants, animals, and humans. Typical functions of a healthy soil include the following: store and cycle nutrients and carbon; provide physical stability and support; regulate water and solution flow; sustain biological diversity, activity and productivity; and to filter or buffer degrading organic and inorganic materials.

Soil Health in Alaska

The concept of managing soil health to address resource concerns is starting to catch on in Alaska. Resource concerns such as young, nutrient deprived soils, weed pressure, wind (*Figure 1-1*) and water erosion are not uncommon across the state. The NRCS, Soil and Water Conservation Districts, Tribal Conservation Districts, Plant Materials Center (PMC), Alaska Pacific University and the University of Alaska Fairbanks have been involved in trials to examine several conservation practices and their ability to enhance soil health and, ideally, alleviate these resource concerns for Alaskan farmers.

Figure 1-1. *Fine silts are carried off in the winds near Butte, Alaska. The Plant Materials Center is currently investigating the effects of cover crops on reducing wind erosion.*

The PMC, for example, is currently working on a long-term trial monitoring the effects of multi-species cover crop mixtures in rotation with potato on various physical, chemical, and biological soil health indicators. For five growing seasons a one, two, four, and six species cover crop mixture will be planted in a one, two, or three-year rotation. The PMC is using a no-till drill for the trial and has been pleased with preliminary results combating wind erosion and weed pressure. Similar trials are being conducted across the state with goals to collect physical, chemical, and biological baseline soil data; identify the practices most effective at reducing resource concerns; evaluate the relevancy and usefulness of soil health indicators; monitor the impact conservation practices on overall soil health; educate the public on the outcome and communicate the benefits of managing for soil health; and lastly to develop and update soil health assessment cards for Alaska.

Principles in Soil Health

Four key soil health management principles allow for a highly functional system. These principles include: maximize living roots; maximize biodiversity; maximize soil cover; and minimize disturbance (*Figure 1-2*). The left side of the circle highlights feeding soil organisms. Maximizing diversity refers to both above and below ground diversification of plants and animals. Biodiversity can be increased through crop rotations, cover crop mixtures, and even through integrating a livestock grazing system. Extending the time living roots are in the soil will increase the food available to soil organisms. Maximizing the presence of living roots can be accomplished through eliminating fallow, adding cover crops, and diversifying crop rotation systems.

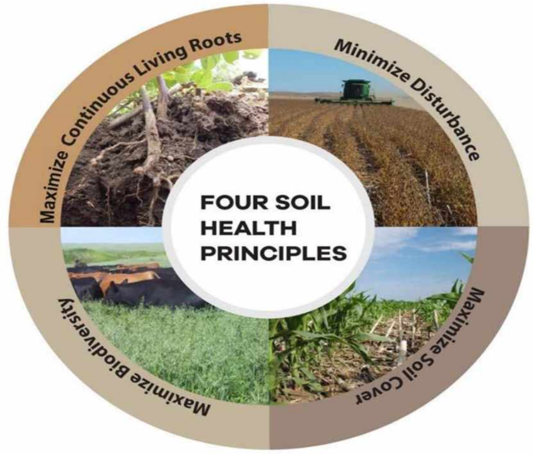

Figure 1-2. *Four soil health principles represented in a circular diagram to emphasize their relationship where each depend upon and complement each other. Diagram courtesy of NRCS.*

The principles illustrated on the right side of the diagram focus on habitat protection (minimize disturbance and maximize cover). Conservation practices using these principles build soil structure, stabilize soil aggregates, increase soil organic matter, and protect the surface from degrading external forces such as wind and water. Soil cover can exist as a living plant or as mulch (dead plant material, thatch, bark chips, etc.). It can protect against drastic temperature fluctuations experienced in Alaska. Soil disturbances may occur through physical (tillage or compaction from heavy equipment), chemical (pesticides, fertilizer) or biological (over-grazing, invasive species) means.

Evaluating Soil Health

Soil health may be assessed through comparing measured values to a reference condition or it can be monitored over time to observe trends and changes in any number of parameters. By utilizing these two methods for evaluating soil health, assessments can be used to achieve the following: make side by side comparisons of different soil management systems to determine their relative effects on soil quality; take measurements on the same field over time to monitor soil quality as affected by soil use and management; compare problem areas in a field to the non-problem areas; and compare measured values to a reference soil condition or to the natural ecosystem (Doran, 2001).

Farmers, soil scientists, and conservationists are currently using several soil properties to evaluate soil health. We measure these properties because they act as *indicators*. Soil quality indicators are any physical, chemical or biological property, process or characteristic that can be measured repeatedly to monitor change in the soil. Indicators are used to guide land management decisions. A soil indicator must fulfill the following five criteria: be interpretable; correlate well with ecosystem processes; integrate soil physical, chemical, and biological properties and processes; be accessible to many users; and be sensitive to changes (Doran and Safely, 1997). An indicator must also exhibit simple sampling and analytical methods, low temporal and spatial variability, and be easily replicated in order for it to be fully effective.

Tools for Documenting Indicators

To provide an overall assessment to facilitate the comparison of one soil to another, or the same soil year after year, a process is needed to record and score relevant soil health indicators. The following items are a few examples of how farmers, conservationists, and soil scientists are monitoring soil health.

Soil Health Card

The soil health card is a qualitative tool designed by and for farmers, often in collaboration with local Soil and Water Conservation Districts. These cards are producer friendly and require a minimal number of tools, such as a shovel and a wire flag. They generally do not require sending samples off to a commercial laboratory. This version of the soil health card incorporates physical, biological, and chemical indicators that are familiar to farmers and the general public. Indicators include common properties such as soil tilth, structure, resistance, earthworm count, plant vigor, plant residue, water infiltration, soil resistance, color, and smell. Cards can often be obtained from agencies such as NRCS, Cooperative Extension Service, Soil and Water Conservation Districts, Soil Quality Institute, and online resources. See the Appendix for an example of a soil health card designed for Alaskan farmers.

NRCS Soil Health Card

The NRCS Soil Health Card is also a qualitative tool; however, it is predominantly designed for NRCS conservation planning. This card can be very similar to the soil health card mentioned above, although it may include indicators that require more time, equipment, and expense. Additional tests may include soil respiration, and levels of macro- and micronutrients.

Soil Quality Test Kit

The Soil Quality Test Kit is a quantitative tool, developed by John Doran and associates, Agricultural Resource Service in Lincoln, NE and further enhanced by the Soil Quality Institute and NRCS field staff. The main use is for analyzing trends of soil quality directly on site and in the field. Measurements include respiration, infiltration, bulk density, EC, pH, aggregate stability, soil nitrate test, slaking, and earthworms. The test can be time consuming (4-6 hours) but can be completed in the field. This approach may require assistance from a Soil Scientist as the morphology section is technical.

Not included in this manuscript, but currently under development is a new soil health guide proposed by the NRCS Soil Health Division.

Soil Health Indicators

Physical Indicators

Available Water Capacity (AWC)

Available water capacity refers to the portion of water that can be readily absorbed by plant roots from the soil. It is the amount of water released between the *field capacity* and *permanent* *wilting point*. Field capacity is the percentage of water remaining in a soil after saturation and allowed to drain freely. Permanent wilting point is the moisture content of a soil at which plants begin to wilt and fail to recover under optimum atmospheric conditions. AWC is an indicator of the soils ability to retain water. AWC is affected by soil texture, rock fragment content, organic matter, and compaction. It can be a time consuming and expensive indicator to perform. Conservation practices utilized to improve AWC include residue and tillage management, prescribed grazing, cover crops, and crop rotation.

Aggregate Stability

Soil aggregates are groups of soil particles that bind to each other more strongly than to adjacent particles. Aggregate stability refers to the ability of soil aggregates to resist breakdown when natural or manmade forces are applied (i.e. tillage, wind, and water erosion). Size distribution of dry aggregates can be used to predict resistance to abrasion and wind erosion, while wet aggregate stability suggest how well a soil can resist raindrop impact and water erosion. Aggregate stability is dependent upon biological activity, physical disturbance, soil texture (amount and types of clay) and is a good indicator of organic matter and biological activity. Conservation practices to improve aggregate stability include the following: pest management, prescribed grazing, crop rotation, residue and tillage management.

Soil Slaking

Slaking refers to the breakdown of air-dried soil aggregates when they are immersed in water. This indicator gives the farmer or scientist an instant visual impression of soil quality and functionality. Slaking occurs when the soil aggregates cannot withstand the stresses of water intake. The sooner the soil slakes, the poorer the soil quality. Results of a slake test are influenced by organic matter, soil texture, clay mineralogy and water content. The test is simple and can be done in the field. The NRCS recommends the following management practices to improve slake test results: crop rotation, cover cropping, tillage management, and good grazing practices. Generally speaking, anything to increase soil organic matter will help improve an aggregates ability to withstand the slake test.

Bulk Density

Bulk density is an indicator of soil compaction. Bulk density is determined by acquiring the dry weight of a soil and dividing by its volume. Bulk density is influenced by soil texture, soil depth, and surface land management practices. For example, bulk density increases slightly in early stages of no-till treatment after long term conventional tillage (Schwen et al., 2011). The soil health trial at the Plant Materials Center witnessed similar results after one year (*Figure 1-3*). Determining bulk density can be time consuming unless samples are sent off to a lab. A drying oven (or microwave) is required to process samples, along with a scale to determine the mass. Conservation practices for improving bulk density include crop rotation, residue management, and prescribed grazing.

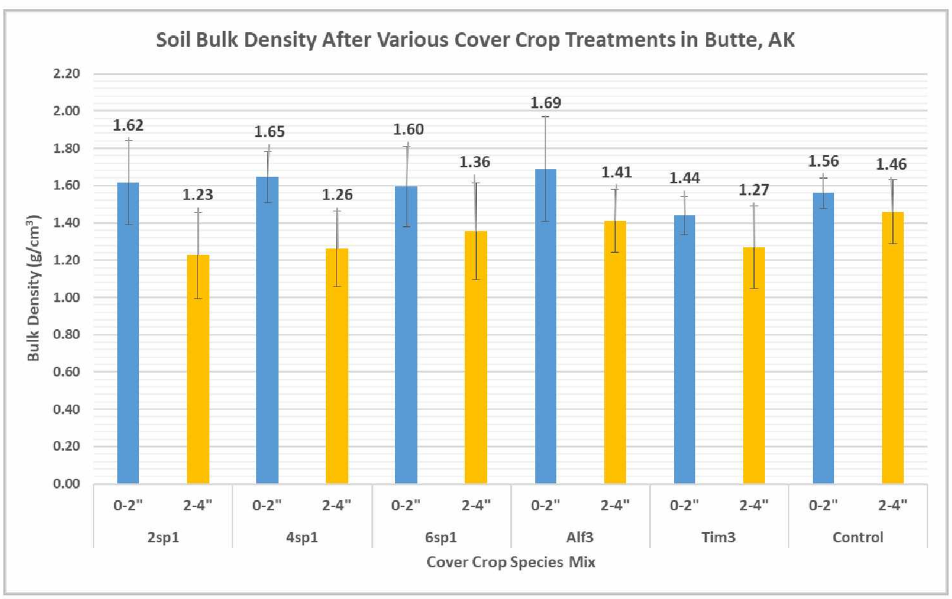

Figure 1-3. *Year one bulk density data from the Plant Materials Center soil health trial. Bulk density at the surface increased when compared to the conventionally tilled control. Cover crop mixes were oat and pea (2sp1); oat, pea, buckwheat and tillage radish (4sp1); oat, rye, pea, alfalfa, buckwheat, and tillage radish (6sp1); Denali alfalfa (Alf3); Timothy grass (Tim3). Vertical bars indicate standard deviation of 8 replications.*

Infiltration

Infiltration is a measurement of velocity at which water enters the soil and, is therefore, highly dependent on soil texture. Typically, infiltration is expressed in inches or millimeters per hour. There are a few negatives for using infiltration rate as an indicator. For example, when comparing infiltration rates of different soils, both sites should be at similar moisture contents when the assessments are taken. It can also take a while for water to infiltrate if the soil is saturated or if it has a restrictive layer. Infiltration is dependent on soil texture and clay mineralogy. Best conservation management practices include activities for increased soil organic matter, minimize surface disturbances, and reduce compaction.

Soil Structure and Macropores

Soil structure affects water and air movement through the soil, influencing a soils ability to function. Structure is the combination or arrangement of soil particles into aggregates. Soil structures can range from small granular to large prismatic. This indicator is rather easy to determine in the field, assuming you have a general concept of soil structure types. Practices that increase soil cover, increase soil organic matter, and avoid compaction will all prove beneficial to increasing soil structure. Common practices include cover cropping, residue/tillage management, crop rotation, and prescribed grazing.

Soil Crusts

Soil crusts are thin layers of non-aggregated soil particles that form at the surface of exposed soil. They develop when broken down soil aggregates dry out and seal out pores after a rainfall or irrigation event. They can range from tenths of an inch to as much as a few inches in thickness. Soil crusts are related to soil texture, sodium content, and soil organic matter. They are most common in fine textured soils such as silts and clays. Conservation practices that increase soil structure, organic matter, and protect the surface would aid in avoiding soil crusting. Common practices include cover crops, crop rotation, residue management, tillage management, salinity and sodic soil management.

Chemical Indicators

Soil Electrical Conductivity (EC):

The capacity of a substance to conduct or transmit electrical current in soils or water is measured in Siemens/meter (or dS/m) and related to dissolved solutes. In non-saline soils EC is used as an indicator of soil moisture and nutrient (nitrate) content. EC is a rather simple indicator to measure and, with proper equipment, can be determined in a matter of minutes. EC is influenced by types of soluble salts in solutions, porosity, soil texture, soil moisture, and soil temperature. High levels of precipitation can flush salts out of a system. Conservation practices that wash soluble salts off of soil and away from rooting zone are effective at decreasing EC.

Soil pH

Soil pH is a measurement of a soil's acidity or alkalinity. This indicator is easy to determine with the right equipment or sampling kit. Soil pH is greatly influenced by the combined effects of the soil forming factors i.e. climate, organisms, landscape, parent material, and time. Liming and crop rotation can be used to increase soil pH. Applying ammonium based fertilizer, urea, adding acidic residues or sulfur/ferrous sulfate can decrease pH. Increasing soil organic matter can increase buffering capacity.

Biological Indicators

Particulate Organic Matter (POM)

Particulate organic matter refers to soil organic matter particles less than 2 mm and greater than 0.05 mm. There are several laboratory methods for determining POM, but currently no reliable field methods, making it a costly indicator. Time required in the lab can also be lengthy. Management practices for positively impacting POM include crop rotation, cover crops, manure, compost, no till, strip till, ridge till, and pasture or hay land management practices.

Earthworms

Some would argue that earthworms are not a good indicator in Alaska as they may be invasive, brought here in plant soils or as fishing bait. Regardless of how they arrived, earthworms contribute nutrients to the soil and improve porosity, root development, and tilth. Measuring earthworms in the field is quick and easy. Individual worms are counted within a defined volume. Practices that boost earthworm populations include tillage management, manure application, pH management, crop rotation, proper irrigation and drainage management.

Soil Respiration

Soil respiration refers to the amount of carbon dioxide released from the soil surface. It is a measurement of biological activity and decomposition occurring in the soil. Soil respiration is the result of microbial or faunal activity, or the dissolution of carbonates. Measurements require limited time and can occur in the field with the proper equipment. It can also be sent off to a commercial lab for a fee. Management practices to increase soil respiration include conservation tillage, manure/compost application, deep-rooted crops, cover crops, and good irrigation practices.

Total Organic Carbon (TOC)

Total organic carbon is a measurement of the carbon stored in the soil organic matter. TOC is a difficult measurement to obtain in the field. Attempts have been made to measure carbon with infrared spectroscopy, but the equipment is expensive. Typically, TOC is determined in a commercial lab and is a costly procedure. Management practices to improve TOC include no-till, cover crops, compost and manure applications.

Conservation Practices for Improving Soil Health

A significant number of land management practices are available to farmers today. Five such practices that may be beneficial to Alaskan agriculture are described below.

Cover Cropping

Cover cropping refers to the planting of crops, such as grasses, legumes, or forbs, as a seasonal cover and other land conservation purposes. Cover crops are frequently defined as crops that shield the ground to guard the soil from wind and water erosion and loss of plant nutrients through leaching or runoff (Reeves and Wood, 1994). The living ground cover is planted into or after a cash crop and then destroyed before the next crop is planted. The practice is used to address several resource concerns including wind or water erosion, soil organic matter, biological nitrogen fixation, biodiversity, weed management, providing supplemental forage, soil moisture, capturing and recycling nutrients, and soil compaction. See *Table 1-1* for an example of a six species cover crop mix used at the Alaska Plant Materials Center for a soil health trial.

Table 1-1. *Cover crop mix and seeding rates applied to the six species mix for the soil health trial at AK Plant Materials Center. Mix composition and seeding rates were developed by local Agronomists.*

Common Name	Seed/lbs	% of Mix	Traditional drilled lbs/acre	Seeds/acre	Alaska Seeding rate/acre	lbs/acre	lbs/plot	No-Till Drill Calibration Seeds Per/Ft
Grasses								
Oats	12800	22.5%	80-110	1408000	120	27.0	0.70	5.29
Annual Rye	224000	22.5%	10-20	4480000	20	4.5	0.12	15.43
Legumes								
Field Pea	2500	22.5%	50-80	176000	160	18.0	0.47	.69
Alfalfa	270000	22.5%	8-10	2700000	10	2.3	0.06	9.5
Non-legume Broadleaf								
Buckwheat	20335	5.0%	48-70	1423450	70	3.5	0.41	1.09
Brassica								
Radish	33975	5.0%	8-13	441675	13	.65	0.08	.34

Research has shown benefits from cover crops to include carbon sequestration, weed suppression, and integrated pest management (Dabney et al., 1998). Cover crops increase soil quality by improving biological, chemical, and physical properties including organic carbon content, cation exchange capacity, aggregate stability, and water infiltration (Dabney et al., 1998). They can decrease soil bulk density and compaction (Raper et al., 2000; Ess et al., 1998). Different cover crops, both legumes and cereal, were shown to improve soil aggregation (Kladivko, 2003; Kabir and Koide, 2000). Cover crops reduce sedimentation by protecting the soil surface from direct impact from raindrops. This protection, in turn, reduces the likelihood of aggregate breakdown and subsequent water erosion.

Summer cover crops using limited irrigation and in rotations with deeply rooted small grains minimized wind erosion increased nutrient cycling, increased nutrient use efficiency, and reduced nitrate leaching in coarse textured soils (Delgado et al., 2008). Preliminary data from the AK Plant Materials Center has shown a significant increase in soil organic matter in Timothy (*Phleum pratense var.* Engmo) grass plots (*Figure 1-4*).

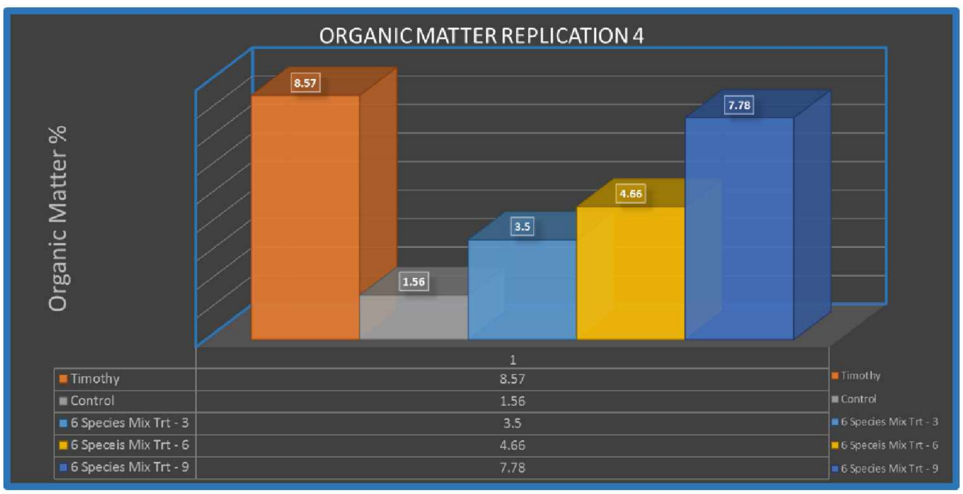

Figure 1-4. *Percent soil organic matter (SOM) in replication four of AK Plant Materials Center study. SOM increased most dramatically in Timothy (Phleum pratense var.* Engmo*) treatment.*

Perhaps most importantly, cover crops provide the soil with living roots throughout the year, increasing soil organic matter via plant roots and microbial and fungal communities. The roots form symbiotic relationships with mycorrhizal fungi. The roots provide critical carbohydrates to the fungi, while the fungi return nutrients to the plant (Ethridge, 2014). Root derived organic matter contributed more to overall soil organic matter than carbon from aboveground plant biomass (Gale and Cambardella, 2000).

Adding cover crops to a farming system may potentially have negative effects. Although cover crops may control erosion, reduce leaching, fix nitrogen, they also use water. In arid regions, for example, cover crops may use soil water that would otherwise be available for the following commodity crop. High carbon to nitrogen ratios in mature grass and cereal crop residue may tie up nitrogen and reduce availability to next year's crop (Snapp et al., 2005). Other negative effects of cover cropping may include the following: additional planning; expense; potential pest or pathogen introduction; incompatibility with current farm equipment; and slowed soil warming and drying in the spring.

Crop Rotation

Crop rotation means growing various crops on the same piece of land in a planned sequence. This sequence may involve growing high residue producing crops such as corn or wheat in rotation with low residue producing crops such as vegetables or soybeans. It could also involve growing forage crops in rotation with various field crops. Crop rotation is used to reduce wind and water erosion, improve soil health, conserve water, manage saline seeps, manage balance of plant nutrients, supply nitrogen through biological nitrogen fixation, pest management, provide feed for livestock, or food and cover for wildlife.

The use of cover crops in rotation may have a significant effect on physical soil properties. Winter cover crops associated with no-till had positive effects on aggregate stability, reduced bulk density, improved porosity, increased available water holding capacity, and reduced penetration resistance (Villamil et al., 2006). Fibrous rooted, high residue crops such as grass and small grains are effective for improving organic matter. Perennial plants used for forage can be effective in crop rotations due to increases in soil organic matter and reduced erosion. A study by Havlin et al. (1989) claims that crop management systems that include rotations with high residue-producing crops and maintenance of surface residue cover (with reduced tillage) result in greater soil organic carbon and nitrogen to potentially improve soil productivity.

Studies have also shown that crop rotation may not always be effective. For example, occasionally, crop rotations did not stabilize soil aggregates despite a higher content of soil organic matter

(Benjamin et al., 2008). The effect on physical soil properties may vary depending on the crop being grown (Blanco-Canqui et al., 2013).

Manure and Compost Application

The addition of compost or manure to a site can greatly influence physical, chemical, and biological properties. Manured soils had a higher content of organic matter and higher populations of microfauna than conventionally fertilized soils (Edmeades, 2003). Edmeades (2003) also claims physical characteristics such as bulk density, porosity, hydraulic conductivity, and aggregate stability benefited more from manure application than fertilizer applications. Fraser et al. (1988) found that soil bacteria and fungi population, enzyme activity, and microbial biomass were significantly higher in soils amended with manure.

In a study comparing commercial fertilizer (control) to fertilizer combined with farmyard manure, soil organic carbon content (in the upper 45cm) increased for the treatment with manure. Applications with the farmyard manure reduced bulk density and improved infiltration rates more than the control (Bhattacharyya et al., 2007).

Studies are currently being conducted in Alaska to measure the impact of composted seaweed and fish waste. Data should be available within the next 5 years.

Rotational Grazing

Under rotational grazing, only one portion of the pasture is grazed at a time while the remainder is under rest. Pastures are subdivided into smaller areas and livestock are moved from paddock to paddock throughout the season. Resting grazed paddocks allows forage plants to regrow, deepen the root systems and increase overall production. This process allows an increased potential for soil organic matter accumulation. Rotational grazing can also improve long-term pasture quality and fertility by allowing for more uniform manure distribution.

A study completed by Naeth et al. (1991), indicated that low intensity and/or early season grazing had a more positive impact on soil organic matter than high intensity grazing. Medium and fine sized particles of soil organic matter demonstrated greater likelihood for decomposition and incorporation into the soil profile on grazed paddocks (Naeth et al., 1991).

Residue and Tillage Management

Residue and tillage management is the process of limiting soil disturbance to manage the amount, orientation, and distribution of crop and plant residue on the soil surface year-round. No-till is a practice that leaves the crop residue undisturbed from harvest through planting, except perhaps, for narrow strips that cause minimal soil disturbance (strip-till). Crop residues (stalks, stubble, leaves, and seeds) are generally left behind in the field after the crop has been harvested. The residue serves as protection from wind and water erosion. Over time, and when used in conjunction with cover crops, the residue is broken down through increased microbial activity (*Figure 1-5*), thereby increasing soil organic matter. This practice can be used to increase organic matter content, reduce energy use, reduce wind and water erosion, reduce tillage induced particulate emissions, increase water use efficiency, and provide food and cover for wildlife.

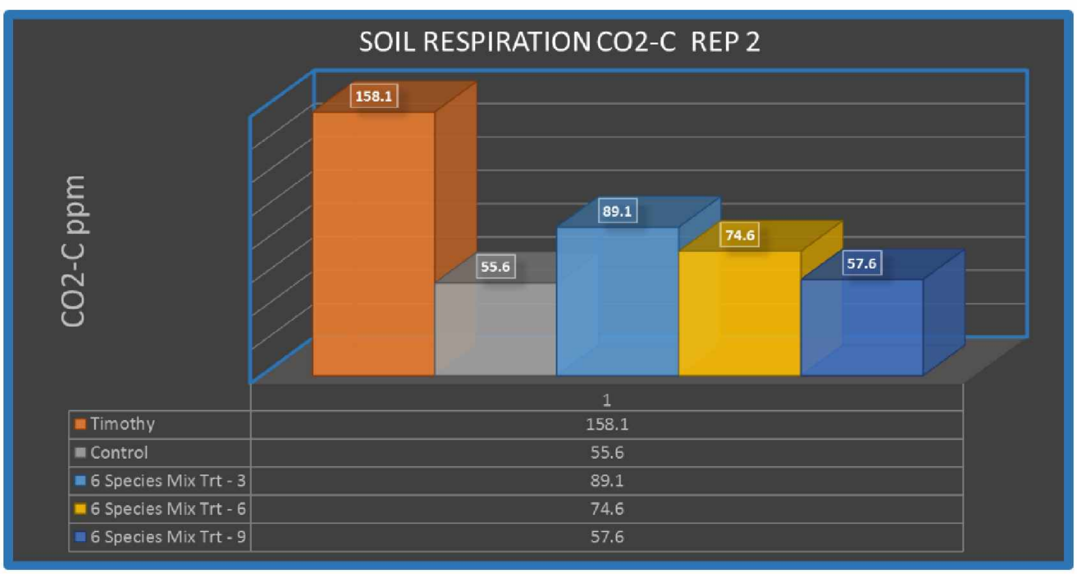

Figure 1-5. *Amount of CO_2-C (ppm) released in 24 hours from soil microbes in soil from the AK Plant Materials Center soil health study. In most cases, the higher the number, the more fertile the soil. The six-species mix includes oats, rye grass, field pea, Denali alfalfa, buckwheat, and tillage radish. Data are for replication 2 only.*

Studies have shown that residue and tillage management may have a positive impact on soil structure, AWC, infiltration, SOM, and aggregate stability. Aziz et al. (2013) estimated that soil quality index was significantly higher in soil under no-till than conventional tillage. No-till reduces loss of phosphorus in runoff and nitrate through leaching (Soane et al., 2012). The impact of tillage practices varies with length of use, soil temperature and moisture regimes, and other soil limitations. Generally, long term use of no-till along with high residue crops during the growing season will enhance aggregate stability, leading to increased available water capacity and infiltration rates (Brock, 1999).

Studies on tillage practices have been conducted in climates similar to Alaska. Franzluebbers and Arshad (1996), when conducting a conventional vs. zero tillage study in Canadian Prairies, found that the arctic climate hindered any acceleration of decomposition of soil organic matter and crop residues due to soil disturbance with conventional till. They claim that soil organic carbon and active soil carbon did not improve as they would in less harsh climatic environments. In a separate Canadian study, Campbell et al. (1995) found, compared to conventional tillage, no-till increased organic carbon and nitrogen concentrations in the 0 to 7.5 cm soil depth range.

A study conducted in Alaska (Sharrat et al., 2006) focused on the impact of tillage treatments on infiltration, water retention, and saturated hydraulic conductivity. No-till resulted in greater saturated hydraulic conductivity and retained more water. They (Sharrat et al., 2006) also concluded that minimum tillage (i.e. spring disk or autumn chisel) was the most viable options for maximizing infiltration.

Further research to determine the impact of tillage treatments is underway across Alaska. As previously discussed, the Plant Materials Center in Palmer, Alaska, is implementing a five-year study on no-till management. Additionally, trials on reduced till production methods are underway in the Homer area of Alaska.

CHAPTER 2: SOIL HEALTH CARD FOR ALASKAN FARMERS

ALASKA SOIL HEALTH CARD GUIDE

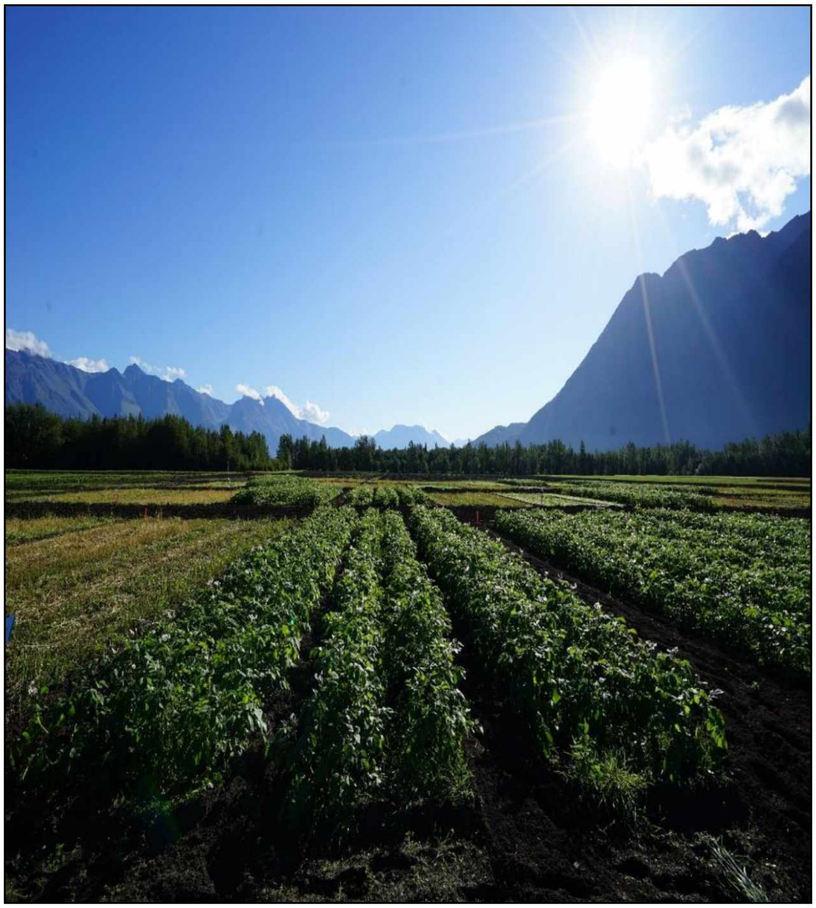

Figure 2-1. *A potato plot from the soil health trial being conducted at AK Plant Materials Center.*

This section is intended to be used independently from Chapter 1 and in combination with the Alaska Soil Health Card in the Appendix.

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What is soil health?

Soil health can be defined as the ability of a soil to function on its own. Typical functions of a healthy soil include the following: store and cycle nutrients and carbon; provide physical stability and support; regulate water and solution flow; sustain biological diversity, activity and productivity; and filter, buffer, degrading organic and inorganic materials.

How do we know if the soil is healthy?

There are two ways to assess soil health: take measurements periodically over time to monitor trends or changes in soil health; and compare measured values to a reference soil condition. By utilizing these two ways of assessing soil health, assessments can be used to achieve the following: make side by side comparisons of different soil management systems to determine their relative effects on soil quality; take measurements on the same field over time to monitor soil quality as affected by soil use and management; compare problem areas in a field to the non-problem areas; and compare measured values to a reference soil condition or to the natural ecosystem (Doran et al, 2001).

What do we use to measure soil'function?

Farmers, soil scientists, and conservationists are currently using certain soil properties to evaluate soil health. We measure these properties because they act as *indicators*. Soil quality indicators are any physical, chemical, or biological property, process and characteristics that can be measured to monitor change in the soil. Indicators are used to guide land manager decisions. A soil indicator must fulfill the following 5 criteria: be interpretable; correlate well with ecosystem processes; integrate soil physical, chemical, and biological properties and processes; be accessible to many users; and be sensitive to changes (Doran, 1997). An indicator must also exhibit simple sampling and analytical methods, low temporal and spatial variability, and be easily replicated in order for it to be fully effective.

When is the best time to assess the soil indicators?

The assessment calendar below shows the best times of year to observe the soil indicators. Times will vary depending on crops grown and where you are in Alaska. These are just recommended times. It is more important that you are consistent with the times sampled from year to year. It is also important that you make note of weather condition (air and soil) at the time of sampling. Many of these parameters are sensitive to climate. Try to sample in similar conditions year to year. Accuracy will increase with several representative sites within a field.

Table 2-1. *A suggested assessment calendar for Alaska, specifically the Matanuska Susitna Valley. This calendar can be amended for multiple areas across the state.*

Suggested Assessment Calendar					
	Before Planting	Active Crop Growth		After Termination	
Indicator	Early Spring	Late Spring	Summer or Early Fall	Late Fall	Winter
Infiltration	x	x	x	x	
Slaking	x	x	x	x	
Soil Structure	x	x	x	x	
Soil Crusts	x	x	x	x	
Resistance	x	x	x	x	
pH	x	x	x	x	x
Biological Diversity	x		x		x
Earthworms	x	x		x	x
Crop Residue	x	x	x	x	x
Soil Smell	x	x	x	x	
Crop/Weed Vigor		x	x		
Root Growth		x	x		

Using the indicator criteria on the soil health card

Follow the instructions described within the "how to assess" section of this guide and rate your observations based on the indicator criteria tables provided for each indicator.

NOTE: The rating scale runs from 1 (least desirable) to 10 (most desirable).

Does water infiltrate quickly?

What is infiltration?

Infiltration refers to the downward movement of water into the soil after a rainfall or irrigation event. The velocity at which the water enters the soil is often measured in inches or millimeters per hour. The rate of infiltration decreases as the soil becomes saturated.

What influences infiltration?

There are a number of factors influencing infiltration rate. Soil texture and clay mineralogy play a significant role. The large pore spaces present in sandy soils allow for water to infiltrate more rapidly than do the small pores of a clayey soil. Some clayey soils, due to mineralogy or high clay content, may shrink and open large cracks, therefore allowing greater rates of infiltration on soils which normally experience low rates of infiltration.

Why is infiltration important?

Infiltration demonstrates the soils ability to allow water movement into and throughout the soil profile. Once in the profile, the water becomes available for root uptake and aids in plant growth. Soil with good infiltration has little runoff and resists erosion.

How is infiltration assessed?

Infiltration is best measured after a rainfall when you think the soil is saturated. Observe and record the duration of any ponding that remains on the surface. Use the indicator criteria below to rate and record your soil.

Table 2-2. *Indicator criteria for water infiltration assessment.*

Least Desirable	Indicator Criteria	Most Desirable
1, 2, 3	**4,5,6,7**	**8,9,10**
ponding remains 48 hrs after rain/irrigation	ponding remains 24 hours after rain/irrigation	no ponding after rain/irrigation

Does soil stay together when placed in water?

What is soil slaking?

Slaking refers to the breakdown of air-dried soil aggregates when they are immersed in water. This indicator gives the farmer an instant visual of soil quality and functionality. Slaking occurs when soil aggregates cannot withstand the stresses of water intake. The sooner the soil slakes, the poorer the soil quality. The soils ability to withstand slaking is influenced by organic matter content, soil texture, clay mineralogy, and water content.

Figure 2-2. *Preferred method for slake test illustrating No-till (left) and conventionally tilled (right) soils. Photo courtesy of the Natural Resources Conservation Service.*

How does soil slaking relate to soil function?

Soils that withstand slaking demonstrate stabile soil aggregates. Stabile aggregates are more resistant to soil erosion and allow a soil to maintain quality structure which helps provide air and water for plants during rain events. Soils that slake will block soil pores, form soil crusts, reduce infiltration and water movement through the soil, increase runoff and erosion.

How does soil management impact slaking?

Conservation practices that lead to soil slaking include the following: conventional tillage; pesticide application that harms soil organisms that cycle organic matter; and burning, harvesting or removing of residue.

Conservation practices that reduce soil disturbance and manage soil organic matter content will help minimize slaking. These practices include the following: crop rotation; cover crops; prescribed grazing; and residue and tillage management.

How do we perform and assess a slake test?

Soil slaking is determined by putting soil fragments or aggregates in water and estimating the degree or percentage of slaking. Estimate the remaining portion of soil that held together.

Soils can be placed in a jar as depicted in the photo above or in a custom slake kit as seen to the right.

Figure 2-3. *Common set up for slake test. Photo courtesy of the Natural Resources Conservation Service.*

Table 2-3. *Indicator criteria for the soil slake test.*

Least Desirable	Indicator Criteria	Most Desirable
1, 2, 3	**4,5,6,7**	**8,9,10**
no soil aggregates intact	50% of soil aggregates remain intact	all aggregates remain intact

Does the soil have good structure and tilth?

What are soil structure and tilth?

Soil structure is the arrangement of soil particles into aggregates, secondary units or granules, held together by substances such as organic materials, silica, clay and iron oxides. There are many classes of soil structure including granular, blocky, prismatic, columnar, platy, single grained and massive (*Figure 2-4*). Soil tilth is the physical condition of the soil in relation to plant growth. It suggests how easily a soil can be tilled and a seedbed prepare.

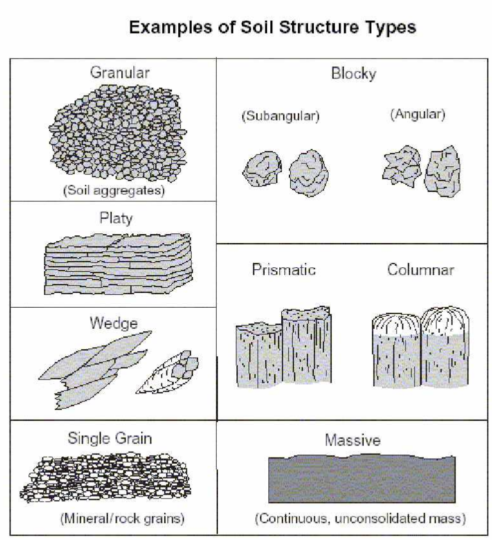

Figure 2-4. *Illustration of common soil types. Courtesy of nesoil.com*

Why is soil structure important to soil health?

Soil structure plays a significant role in how water and air move through soil, greatly influencing the soils ability to sustain life and perform vital soil functions. Key soil functions related to soil structure include: regulating water and solute flow; cycling and storing nutrients; and sustaining biological productivity. Granular structure at the surface is associated with soil high in organic matter. Platy structure is often an indicator of soil compaction. Conservation practices which result in improved soil structure include: cover cropping; crop rotation; prescribed grazing; residue and tillage management.

How do we assess soil structure?

Dig a hole to at least 8 inches. Use a soil knife to remove soil peds (chunks of soil structure) from the pit. Observe and record the shape of soil peds and rate your soil based on the criteria indicators listed below. Make note of various types of structure and the depth at which they occur.

Note: It is possible to have multiple types of structure within the same hole. For example, you may have granular structure from 0-4 inches, but blocky or platy structure below.

Table 2-4. *Indicator criteria for soil structure assessment.*

Least Desirable	**Indicator Criteria**	**Most Desirable**
1, 2, 3	**4,5,6,7**	**8,9,10**
powdery when dry, hard clods, platy structure	some granular structure, little platiness	mostly granular structure

Do soil crusts form after rain events?

What are soil crusts?

Figure 2-5. *Soil crusts on conventionally tilled field in Butte, AK. Photo by Cory Cole*

Soil crusts are the thin layers of non-aggregated soil particles that form on the surface of an exposed soil. They develop when broken down soil aggregates dry out and seal out pores after a rainfall or irrigation event. Soil crusts reduce infiltration and increase risk of erosion. They can range from tenths of an inch to as much as a few inches. Soil crusts are related to soil texture, sodium content, and soil organic matter. They are most common in fine textured soils such as silts and clays. Conservation practices that increase soil structure, organic matter, and protect the surface would aid in avoiding soil crusting. Common practices include cover crops, crop rotation, residue management, tillage management, salinity and sodic soil management.

How are soil crusts assessed?

Make an observation of the soil surface after a rain or irrigation event. Allow the surface ample time to dry. Estimate percent surface crust and use the indicator criteria below to rate your soil.

Table 2-5. *Indicator criteria for soil crust assessment.*

Least Desirable	Indicator Criteria	Most Desirable
1, 2, 3	4,5,6,7	8,9,10
crusts common after rain/irrigation event	50% of field has crust after rain/irrigation event	no crusting after rain/irrigation event

Is the soil free of compacted layers?

What is soil compaction?

Compacted soil is dense and can have platy structure (see photo on right). The following practices can lead to soil compaction: heavy equipment on same area; consistent plowing or disking to same depth; removing crop residue; limited crop rotation or root depth variability; and overgrazing. Bulk density is a worthy indication of soil compaction. One can calculate bulk density by acquiring the dry weight of a soil and dividing by its volume. Bulk density is influenced by soil texture, soil depth, and surface land management practices.

Figure 2-6. *Platy-like structure resulting from compacted soils. Photo by Cory Cole.*

Why is soil compaction important?

Soil compaction is important because it can restrict air and water movement thorough soil, diminish plant root growth, and reduce ability of organisms to live in the soil. Conservation practices which improve bulk density include crop rotation, residue management, and prescribed grazing.

How do we assess soil compaction?

Compaction should be measured both before spring tillage and during the growing season. Soil moisture can influence your assessment so try to do the test when there is adequate moisture in the soil for crop growth. There are many ways to test for compaction. For this test use a wire flag, hold the wire flag near the flag end and put it vertically into the soil at multiple locations. Record your depth at which the flag begins to bend due to resistance. Rate compaction based on the criteria listed below.

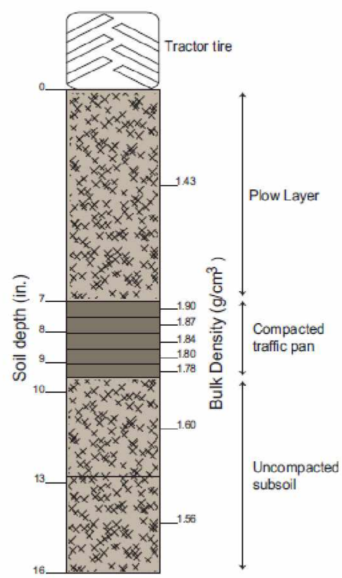

Figure 2-7. *Illustration of compacted soils below the plow layer in a conventionally plowed field. Adapted from The Nature and Property of Soils, 10th Edition.*

Table 2-6. *Indicator criteria for soil compaction and/or bulk density assessment.*

Least Desirable	Indicator Criteria	Most Desirable
1, 2, 3	**4,5,6,7**	**8,9,10**
wire flag bends easily; no penetration; obvious hardpan	need slight force for wire flag penetration	easy penetration of wire flag, absence of hardpan

Is the pH at a desirable level?

What is soil pH?

Soil pH is measure of a soils acidity or alkalinity. Soil pH is greatly influenced by the combined effects of the soil forming factors: climate, organisms, landscape, parent material and time.

Figure 2-8. *Common pH kit available to farmers.*

Why is soil pH important?

It effects plant growth and a soils physical, biological, and chemical processes and properties. Plant growth, yield, and nutrients tend to decrease when pH is low and increase as pH reaches optimum levels. Liming and crop rotation can be used to increase soil pH. Applying ammonium based fertilizer, urea, adding acidic residues or sulfur/ferrous sulfate can decrease pH. Increasing soil organic matter can increase buffering capacity.

How do we assess soil pH?

This indicator is very easy to determine and can be completed rather quickly provided you have the equipment or a sampling kit. Take a soil sample, use a pH kit. Determine optimum pH range for current crop and use the indicator criteria to rate your site.

Figure 2-9. *More expensive pH meter that can be used by soil scientists and farmers. Photo courtesy of NRCS*

Table 2-7. *Indicator Criteria for soil pH.*

Least Desirable	Indicator Criteria	Most Desirable
1, 2, 3	**4,5,6,7**	**8,9,10**
within 1.0 of ideal pH for desired crop	within .5 of ideal pH for desired crop	at ideal pH range for desired crop

Are there living organisms in the soil?

Why are soil organisms important to soil health?

There is an incredible amount of diversity in the soil. Soil organisms range in size from single-celled bacteria, algae, fungi, and protozoa to more complex arthropods and nematodes, all the way up to visible earthworms and insects. Soil organisms serve many roles in the soil system: decompose organic compounds; store and/or fix nitrogen and other nutrients; enhance soil aggregation and porosity; and prey on pests.

How do we assess living organisms?

Soil organisms are less active in hot, dry conditions. Try to assess this indicator when soil is moist and relatively warm. There are a few methods to assess soil organisms. The first method is to simply dig a hole to 8 inches, examine the soil for a specific amount of time (2-3 minutes), record the number of soil organisms you observe and rate your soil based on the indicator criteria below. The pitfall trap and Berlese funnel tests are a bit more time consuming, but should provide more accurate measurements. The procedure for these tests can be found below:

Pitfall Trap and Berlese Funnel Tests

Materials needed

Shovel

cup or mason jar about 6 inches tall

12 ounce jar

funnel

¼ mesh screen

75 watt light bulb

Vegetable oil or rubbing alcohol

Shallow dish

Magnifying glass

Pitfall trap (larger organisms)

1. Dig a hole to the depth of the cup. Place the cup in the hole so that top of the cup is level with the soil surface. Fill soil around the hole.
2. Pour vegetable oil or rubbing alcohol into cup.
3. Remove cup after 1 week and record number of individuals in the cup.

Berlese Funnel (smaller organisms)

1. Place screen in funnel.
2. Fill funnel with top soil collected on the day of assessment.
3. Fill jar with an inch of rubbing alcohol or vegetable oil. Carefully place funnel over cup (or create setup to right).
4. Suspend a light bulb above funnel for a few days, or until soil is very dry.
5. Pour liquid from cup into a shallow dish and use the magnifying glass to count soil organisms. Use the soil indicator criteria listed below to rate your soil.

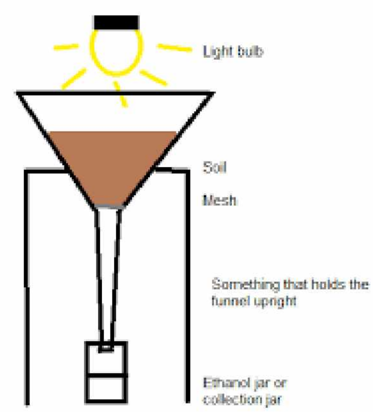

Figure 2-10. *Basic Berlese funnel setup with light funnel and jar to gather soil organisms. Courtesy of geologia.unam.mx*

Table 2-8. *Indicator criteria for soil organisms.*

Least Desirable	Indicator Criteria	Most Desirable
1, 2, 3	**4,5,6,7**	**8,9,10**
little to no diversity in soil organisms; little to no observed individuals	1 to 2 types of organisms; 1-2 individuals of each observed	3 or more types of organisms observed; multiple individuals of each type present

Is there evidence of earthworm activity?

Why are earthworms important to soil health?

Earthworms contribute nutrients to the soil and improve porosity, root development, and tilth. Earthworms mix the soil and break up plant material. Some earthworms bring plant residue down from the surface. Others, via their casts, bring minerals to the surface from deeper down in the soil profile. Earthworm casts contain more organic matter, enzymes, bacterial and plant nutrients than the surrounding soil. Practices that boost earthworm population include tillage management, manure application, pH management, crop rotation, proper irrigation and drainage.

How do we measure earthworm activity?

Measuring earthworms in the field is easy. Using a shovel simply dig a hole to about 8 inches and count the number of worms, burrow holes and worm casts that you see. Rate the indicator based on the criteria below.

Table 2-9. *Indicator criteria for earthworm assessment.*

Least Desirable	Indicator Criteria	Most Desirable
1, 2, 3	**4,5,6,7**	**8,9,10**
0-1 earthworms, holes or casts observed in hole	5 earthworms, holes or casts observed in hole	10 earthworms, holes or casts observed in hole

Does the soil smell earthy?

Why does soil have a smell?

It is technically not the soil we smell, but rather a chemical produced by bacteria within the soil. The smell will be different depending on where the soil is. Healthy, productive soils generally have a fresh, pleasant, earthy smell. Soils with poor drainage often have an ammonia or rotten, sulfur-like smell.

How do we assess soil smell?

When the soil is at ideal moisture for crops, simply dig a hole to about 8 inches. Grab samples from various depths, where things look different, and simply smell the soil. Use the indicator criteria below to rate and record your soil smell.

Table 2-10. *Indicator criteria for soil smell assessment.*

Least Desirable	Indicator Criteria	Most Desirable
1, 2, 3	**4,5,6,7**	**8,9,10**
sulfur, ammonia or metallic smell	little to no smell	earthy smell

Do plant roots grow well?

What is healthy root growth?

A healthy root system is often as extensive as the aboveground biomass. The shape and depth of spreading will depend on the species. Healthy roots have good color and are not restricted by compaction. Root distribution is important because they are the direct link to soil water, air, nutrients, and organisms. A strong root system anchors the plant and supports upward growth.

How do we assess root growth?

Measure root growth at the same time as plant vigor. Using a shovel or a hand trowel, dig a hole around a crop plant to determine how deep and wide the roots extend into the soil. Do your best to separate the soil from the roots and look at overall distribution (are they restricted, wide in extent), root color, and the number of fine roots. Use the criteria below to rate your site.

Table 2-11. *Indicator criteria for root growth assessment.*

Least Desirable	Indicator Criteria	Most Desirable
1, 2, 3	**4,5,6,7**	**8,9,10**
poor root growth; roots run parallel to the surface; discolored or mushy	evidence of fine roots; appear healthy	vigorous, healthy root system with desirable color

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REFERENCES

Acton, D.F., and L.J. Gregorich. 1995. Understanding soil Health. p. 5-10 in the health of our soils-toward sustainable Ag in Canada. Centre for Land and Biological Resources Research, Research Branch, Ag and Agri-Food Canada, Ottawa, ON.

Aziz .I, T. Mahmood, K. R. Islam. 2013. Effect of long term no-till and conventional tillage practices on soil quality. Soil & Tillage Research 131: 28–35.

Benjamin, J.G., M. M. Mikha; and M. F. Vigil. 2008. Organic Carbon Effects on Soil Physical and Hydraulic Properties in a Semiarid Climate. Soil Sci. Soc. Am. J. 72:1357-1362.

Bhattacharyya, R., S. Chandra, R.D. Singh, S. Kundu, A.K. Srivastva, and H.S. Gupta. 2007. Long-Term Farmyard Manure Application Effects on Properties of a Silty Clay Loam Soil under Irrigated Wheat–Soybean Rotation. Soil and Tillage Research 94:386–396.

Blanco-Canqui, H., J.D. Holman, J. Tatarko and T.M. Shaver. 2013. Replacing Fallow with Cover Crops in a Semiarid Soil: Effects on Soil Properties. Soil Sci. Soc. Am. J. 77:1026–1034.

Brock, B.G. 1999. Rx for Soil Quality = Long-Term No-Till. In R. Lal (ed.) Soil Quality and Soil Erosion, Chapter 10. Soil and Water Conservation Society, Ankeny, IA.

Campbell, C.A., B.G. McConkey, R.P. Zentner, F. Selles, and D. Curtin. 1995. Tillage and crop rotation effects on soil organic C and N in a coarse-textured Typic Haploboroll in southwestern Saskatchewan. Soil & Tillage Research 37: 3-14.

Dabney S.M, J.A. Delgato, and D.W. Reeves. 1998. Using winter cover crops to improve soil and water quality. Communications in Soil Science and Plant Analysis 32: 1221-1250.

Delgado, J.A., S. Essah, M. Dillon, R. Ingham, D.K. Manter, A. Stuebe, and R. Sparks. 2008. Sustainable Cover Crop Rotations with Potential to Improve Yields, Crop Quality, and Nutrient and Water Use Efficiencies. Soil and Water Conservation Society Proceedings.

Doran, J.W. and M. Safely. 1997. Defining and assessing soil health and sustainable productivity. In C.E. Pankhurst, B. M. Doube, and V.V.S.R. Gupta (eds.) Biological Indicators of Soil Health, pp. 1-28. CAB International.

Doran, J.W. and T.B. Parkin. 1994. Defining and assessing soil quality. Soil Science Society of America Spec. Publ. 35. SSSA and ASA, Madison, WI.

Doran, John. 2001. The Soil Quality Test Kit Guide. United States Department of Agriculture, ARS NRCS and Soil Quality Institute.

Edmeades, D.C. 2003. The Long-Term Effects of Manures and Fertilizers on Soil Productivity and Quality—A Review. Nutrient Cycling in Agroecosystems 66:165-180.

Ess, D.R., D.H. Vaughanand, and J.V. Perumpral. 1998. Crop Residue and Root Effects on Soil Compaction. American Society of Agricultural Engineers 41(4):1271-1275.

Ethridge, K.R., 2014. Increasing organic matter by using cover crops. USDA NRCS Newsroom http://www.nrcs.usda.gov/wps/portal/nrcs/detail/ks/newroom Accessed April, 2016.

Franzluebbers, A.J. and M.A. Arshad. 1996. Soil organic matter pools with conventional and zero tillage in a cold, semiarid climate. Soil & Tillage Research 39:1-11.

Fraser, D.G., J.W. Doran, W.W. Sahs, and J.W. Lesong. 1988. Soil Microbial Populations and Activities under Conventional and Organic Management. Journal of Environmental Quality 17:585-590.

Gale, W.J., and C.A. Cambardella, 2000. Carbon dynamics of surface residue- and root-derived organic matter under simulated no-till. Soil Science Society of America Journal. 64: p. 190-195

Havlin, J.L., D.E. Kissel, L. D. Maddux, M. Claassen and J.H. Long. 1989. Crop rotation and tillage effects on soil organic carbon and nitrogen. Soil Science Society of America Journal. Vol. 54 No. 2, p. 448-452.

Kabir, Z., and R.T. Koide. 2000. The Effect of Dandelion or a Cover Crop on Mycorrhiza Inoculum Potential, Soil Aggregation, and Yield of Maize.

Karlen, D.L., M.J. Mausbach, J.W Doran, R.G. Cline, R.F. Harris, and G.E. Schuman. 1997. Soil Quality: A concept, definition, and framework for evaluation. Soil Science Society of America Journal. 61:4-10.

Kladivko, E. 2003. Soil Quality and Nitrogen Conservation with Annual Ryegrass Cover Crops in Indiana. Interim final report to Oregon Ryegrass Growers' Seed Commission, Purdue University.

Naeth, M. A., A.W. Bailey, D.J. Pluth, D.S. Chanasyk and R.T. Hardin. 1991. Grazing impacts on litter and soil organic matter in mixed prairie and fescue grassland ecosystems of Alberta. Journal of Range Management. Vol. 44, No. 1. p. 7-12.

Raper, R.L., D.W. Reeves, C.H. Burmester, and E.B. Schwab. 2000. Tillage Depth, Tillage Timing, and Cover Crop Effects on Cotton Yield, Soil Strength, and Tillage Energy Requirements. Applied Engineering in Agriculture 16(2):379-385.

Reeves, D.W., and C.W. Wood, 1994. A sustainable winter-legume conservation tillage system for maize: Effects on soil quality. Proc. 13th conference of ISTRO, Vol. II. The Royal Veterinary and Ag. Univ. and Danish Inst.

Romig, D.E., M.J. Garlynd, R.F. Harris, and K. McSweeney. 1995. How farmers assess soil health and quality. J. of Soil and Water Conservation. 50:229-236.

Schwen, A., G. Bodner, P. Schol, G.D. Buchan, and W. Loiskandl. 2011. Temporal dynamics of soil hydraulic properties and water conducting porosity under different tillage. Soil and Tillage Research 113: 89-98.

Sharratt, B., M. Zhang, and S. Sparrow. 2006. Twenty years of conservation tillage research in subarctic Alaska II. Impact on soil hydraulic properties. Soil & Tillage Research. 91:82-88.

Soane, B.D., B.C. Ball, J. Arvidsson, G. Basch, F. Moreno, and J. Roger-Estrade. 2012. No-till in northern, western and south-western Europe: A review of problems and opportunities for crop production and the environment. Soil & Tillage Research. 118: 66-87.

Snapp, S.S., S.M. Swinton, R. Labarta, D. Mutch, J.R. Black, R. Leep, J. Nyiraneza, and K. O'Neil. 2005. Evaluating Cover Crops for Benefits, Costs, and Performance within Cropping System Niches. Agronomy Journal 97:322–332.

Villamil, M.B., G.A. Bollero, R.G Darmondy, F.W. Simmons, and D.G Bullock. 2006. No-till corn/soybean systems including winter cover crops: effects on soil properties. Soil Science Society of America Journal 70:1936-1944.

Weil, Ray R. and Nyle C. Brady. 2016. *The Nature and Properties of Soils*, Fifteenth Edition. Pearson, Columbus.

APPENDICES

ALASKA SOIL HEALTH CARD – FRONT

HOW TO USE THE SOIL HEALTH ASSESMENT CARD

- Complete all site information (landowner name, describer, soil type, soil moisture, etc.).
- Record site history.
- Follow the instructions within the AK Soil Health Guide to rate the 10 indicators.
- Place an 'X' between 1 and 10 to rate the indicator based on the indicator criteria. Make comments to support your decision.
- Tally your score and repeat assessment as needed.

Required Tools: *shovel, soil slake test kit, soil knife, wire flag, pH kit and field sheets. Optional: soil bags to collect samples for further laboratory analysis.*

Why should we assess our Soil?

-evaluate soil management practices.

-determine trends.

-guide land manager decisions.

-focus efforts on maintaining and improving the condition of the soil.

Diagram courtesy of NRCS Soil Health Division

SITE HISTORY

Current Crop: ______________________________

Previous Year's Crop: ________________________

Cropping History: ___________________________

Current Tillage: _____________________________

Tillage History: _____________________________

Other mgmt. practices (fertilizer, herbicides, etc.):

____

____

____

SITE SKETCH:

What is Soil Health?

Soil Health is the ability of a soil to function on its own, as a living ecosystem that can sustain plants, animals, and humans. Healthy soil provides the following functions: aeration for root growth, store and cycle nutrients and carbon; physical stability and support; regulate water and solution flow; sustain biological diversity, activity and productivity; filter, buffer, degrade organic and inorganic materials; reduce disease and pests problems; improve yield stability; and reduce runoff and erosion

FOUR SOIL HEALTH PRINCIPLES

Soil Disturbance: Physical disturbance such as tillage, or compaction from heavy equipment; chemical disturbances may include fertilizer and pesticides; biological disturbances include over-grazing or invasive species.
Soil Cover: This can include any living plant in the canopy and various forms of mulch.
Biodiversity: Variation of life forms (plants, animals, and microorganisms) within a given field or ecosystem.
Living Roots: maximizing living roots can be accomplished through eliminating fallow, diverse crop rotations, adding cover crops.

ALASKA SOIL HEALTH CARD - BACK

Alaska Soil Health Assessment Card

Site Information

Landowner:	Borough:	Observers:	Date:
Tract/Field ID:	Soil Mapunit:	Soil Name:	Current Soil Moisture: Dry Moist Saturated
Avg. Precip:	Additional Site Comments:		
% Slope:			

	Indicator	Comments	1	2	3	4	5	6	7	8	9	10	Least Desirable 1, 2, 3	Indicator Criteria 4,5,6,7	Most Desirable 8,9,10
			least desirable → most desirable												
Physical	Infiltration												ponding remains 48 hrs after rain/irrigation	ponding remains 24 hours after rain/irrigation	no ponding after rain/irrigation
Physical	Soil Slaking/Water Stable Aggregates												no soil aggregates intact	50% of soil aggregates remain intact	all aggregates remain intact
Physical	Soil Structure/Tilth												powdery when dry, hard clods, platy structure	some granular structure, little platiness	mostly granular structure
Physical	Soil Crusts												crusts common after rain/irrigation event	50% of field has crust after rain/irrigation event	no crusting after rain/irrigation event
Physical	Resistance/Bulk Density												wire flag bends easily; no penetration; obvious hardpan	need slight force for wire flag penetration	easy penetration of wire flag, absence of hardpan
Chemical	pH												within 1.0 of ideal pH for desired crop	within .5 of ideal pH for desired crop	at ideal pH range for desired crop
Biological	Biological Diversity												little to no diversity in soil organisms; little to no observed individuals	1 to 2 types of organisms; 1 to 2 individuals of each observed	3 or more types of organisms observed; multiple individuals of each type present
Biological	Earthworms												0-1 earthworms, holes or casts observed in hole	5 earthworms, holes or casts observed in hole	10 earthworms, holes or casts observed in hole
Biological	Soil Smell												sulfur, ammonia or metallic smell	little to no smell	earthy smell
Biological	Root Growth												poor root growth; roots run parallel to the surface; discolored or mushy	evidence of fine roots; appear healthy	vigorous, healthy root system with desirable color

TOTAL SCORE: